(4)

David Taylor Research Center

Bethesda, Maryland 20084-5000

DTRC/SME-88/36 February 1990

Ship Materials Engineering Department

Research and Development Report

ENGINEERING DESIGN AND DEVELOPMENT OF PORTABLE SMOKE CURTAINS

by

Lisandro Vazquez de Jesus

and

Richard Carey

DTRC/SME-88/36 Engineering Disign and Development of Portable Smoke Curtains

MAJOR DTRC TECHNICAL COMPONENTS

CODE 011 DIRECTOR OF TECHNOLOGY, PLANS AND ASSESSMENT

12 SHIP SYSTEMS INTEGRATION DEPARTMENT

14 SHIP ELECTROMAGNETIC SIGNATURES DEPARTMENT

15 SHIP HYDROMECHANICS DEPARTMENT

16 AVIATION DEPARTMENT

17 SHIP STRUCTURES AND PROTECTION DEPARTMENT

18 COMPUTATION, MATHEMATICS & LOGISTICS DEPARTMENT

19 SHIP ACOUSTICS DEPARTMENT

27 PROPULSION AND AUXILIARY SYSTEMS DEPARTMENT

28 SHIP MATERIALS ENGINEERING DEPARTMENT

DTRC ISSUES THREE TYPES OF REPORTS:

1. **DTRC reports, a formal series,** contain information of permanent technical value. They carry a consecutive numerical identification regardless of their classification or the originating department.

2. **Departmental reports, a semiformal series,** contain information of a preliminary, temporary, or proprietary nature or of limited interest or significance. They carry a departmental alphanumerical identification.

3. **Technical memoranda, an informal series,** contain technical documentation of limited use and interest. They are primarily working papers intended for internal use. They carry an identifying number which indicates their type and the numerical code of the originating department. Any distribution outside DTRC must be approved by the head of the originating department on a case-by-case basis.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3 DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) DTRC/SME-88/36	5 MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION David Taylor Research Center 6b. OFFICE SYMBOL (If applicable) DTRC	7a. NAME OF MONITORING ORGANIZATION Naval Sea Systems Command (SEA 05R32)
6c. ADDRESS (City, State, and ZIP Code) Bethesda, Maryland 20084	7b. ADDRESS (City, State, and ZIP Code) Washington, DC 20362
8a. NAME OF FUNDING/SPONSORING ORGANIZATION Naval Sea Systems Command 8b OFFICE SYMBOL (If applicable) SEA 05R32	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code) Washington, DC 20362	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. 63514N; PROJECT NO. S1565-SL; TASK NO; WORK UNIT ACCESSION NO. 378559

11. TITLE (Include Security Classification)

ENGINEERING DESIGN AND DEVELOPMENT OF PORTABLE SMOKE CURTAINS

12. PERSONAL AUTHOR(S)

Lisandro Vazquez de Jesus and Richard Carey

13a. TYPE OF REPORT	13b TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15 PAGE COUNT
Research & Development	FROM _____ TO _____	February 1990	23

16. SUPPLEMENTARY NOTATION

17. COSATI CODES		
FIELD	GROUP	SUB-GROUP

18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)

Smoke Spread; Fire Fighting; Smoke Curtailment; Smoke Penetration; Portable Smoke Curtain

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Four portable smoke curtain prototypes were developed and evaluated in a combined effort between this Center and the Naval Research Laboratory. The portable smoke curtain evaluations were conducted on ALBERT E. WATTS at the United States Coast Guard Fire and Safety Detachment, Mobile Alabama. Two designs effectively controlled the spread of smoke -- the two-strip design for use in archways and doors and the blanket design for use on hatches. Portable smoke curtains reduce gas flow both in and out of the fire compartment, which reduces oxygen to the fire and the spread of smoke. Additionally, they reduce the temperature on the non-fire side of the curtain, and facilitate smoke removal and fire fighting, while allowing the introduction of equipment. Engineering drawings and installation folding procedures were prepared and are included in this report.

20 DISTRIBUTION/AVAILABILITY OF ABSTRACT ☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED
22a. NAME OF RESPONSIBLE INDIVIDUAL Lisandro Vazquez de Jesus	22b TELEPHONE (Include Area Code) (301) 267-4993 22c OFFICE SYMBOL Code 2833

DD FORM 1473, 84 MAR 83 APR edition may be used until exhausted. All other editions are obsolete

SECURITY CLASSIFICATION OF THIS PAGE

★ U.S. Government Printing Office: 1988—607-044

UNCLASSIFIED

CONTENTS

FIGURES

TABLE

ABBREVIATIONS

cm	Centimeters
DC/FF	Damage Control/Fire-Fighting
kg	Kilograms
kg/m	Kilograms per meter
kg/m^2	Kilograms per square meter
lb/ft	Pounds per foot
m	Meters
oz/yd^2	Ounces per square yard
USCG	United States Coast Guard

ABSTRACT

Four portable smoke curtain prototypes were developed and evaluated in a combined effort between this Center and the Naval Research Laboratory. The portable smoke curtain evaluations were conducted on ALBERT E. WATTS at the United States Coast Guard Fire and Safety Detachment, Mobile, Alabama. Two designs effectively controlled the spread of smoke -- the two-strip design for use in archways and doors and the blanket design for use on hatches. Portable smoke curtains reduce gas flow both in and out of the fire compartment, which reduces oxygen to the fire and the spread of smoke. Additionally, they reduce the temperature on the non-fire side of the curtain, and facilitate smoke removal and fire fighting, while allowing the introduction of equipment. Engineering drawings and installation folding procedures were prepared and are included in this report.

ADMINISTRATIVE INFORMATION

The work reported herein is described in Task Statement FFSE-110-F, "Portable Smoke Curtains," and was performed under Program Element 63514N, Project S1565-SL, and Center Work Unit 1202-700. Mr. C. Pohler, NAVSEA (SEA 05R23), was the program manager; the technical agent was Mr. M. Campbell, NAVSEA (SEA 55X22). The work was performed by the Chemical Engineering Processes Branch, M. Greenberg, Head. The project engineer was Mr. Lisandro Vazquez.

INTRODUCTION

The uncontrolled spread of smoke through a ship during a fire causes loss of visibility and a lack of clean breathing air, which makes it difficult for the fire-fighting crew to find and extinguish the fire, and results in extensive damage to the ship and possible loss of human lives.

Portable smoke curtains proved to be a simple and effective enhancement to fire fighting for the British Navy after it was found that the uncontrolled spread of smoke was a prime factor in the loss of one of their ships, HMS SHEFFIELD.

In 1985, the Damage Control/Fire-Fighting (DC/FF) working group recommended that the Naval Sea System Command (NAVSEA) investigate the use of portable smoke curtains on U.S. Navy ships. NAVSEA, in turn, requested that this Center design, develop, and evaluate portable smoke curtains to be used in the Fleet.

OBJECTIVE

Our objective was to develop several types of portable smoke curtains that could be implemented throughout the Fleet.

APPROACH

Our approach to this task was to:

- Develop and evaluate smoke curtain prototypes,
- Develop methods to hold the curtain in position,
- Develop installation techniques,
- Evaluate the prototypes under live fire conditions using Navy firefighters,
- Develop folding techniques for storage and ease of handling, and
- Prepare portable smoke curtain engineering drawings based on our findings.
- Evaluate performance under live fire conditions.

DESIGN AND DEVELOPMENT

ENGINEERING DESIGN

We designed four types of portable smoke curtains; a prototype of each was manufactured using four different materials. The four curtain designs were:

1. Two-strip design,
2. Multiple-panel design,

3. Blanket design, and

4. Tunnel or elephant trunk design.

The two-strip design, Figure 1, was designed for use in doors and archways. It consists of two 78- x 25-in. panels (198 x 63.5 cm) sewn together at the top with a 6-in. (15.2-cm) overlap. Hook and pile strips along the 6-in. (15.2-cm) overlap seal the curtain and reduce the risk of smoke penetrating the curtain overlap. Pressure generated on the fire side of the curtain and the motion of the ship required that a chain (1.0 lb/ft (1.48 kg/m)) be sewn in a sleeve at the bottom of the curtain to reduce separation of the curtain and to help hold the curtain against the lip of the door.

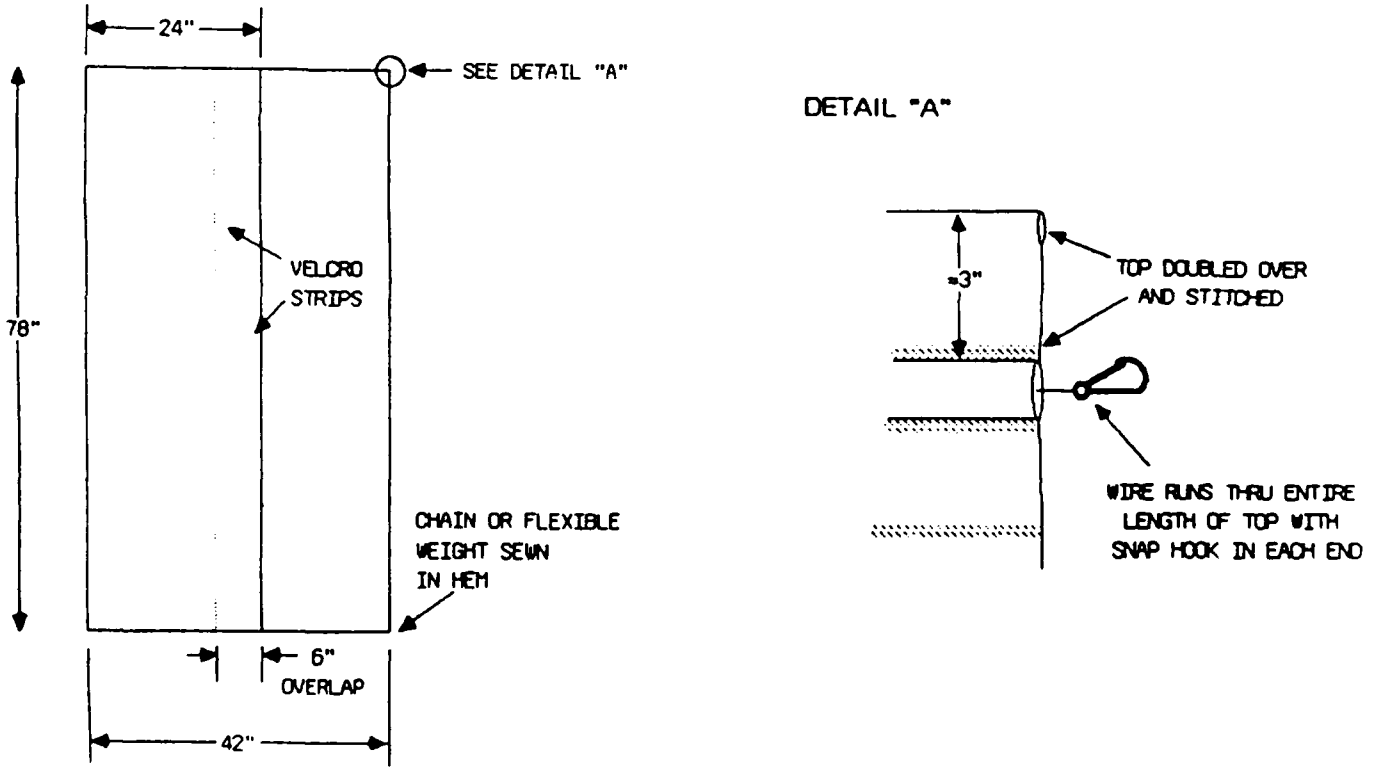


Fig. 1. Two-strip curtain design.

The multiple-strip design, Figure 2, is similar to the two-strip design but consists of four strips sewn together, each measuring 78 x 14 in. (198 x 35.5 cm) with a 4.67-in. (11.8-cm) overlap. This design also is intended for use in doors and archways.

The blanket design, for use on horizontal hatches and shown in Figure 3, consists of a 14.5- x 14.5-ft (4.4- x 4.4-m) panel sewn at the ends.

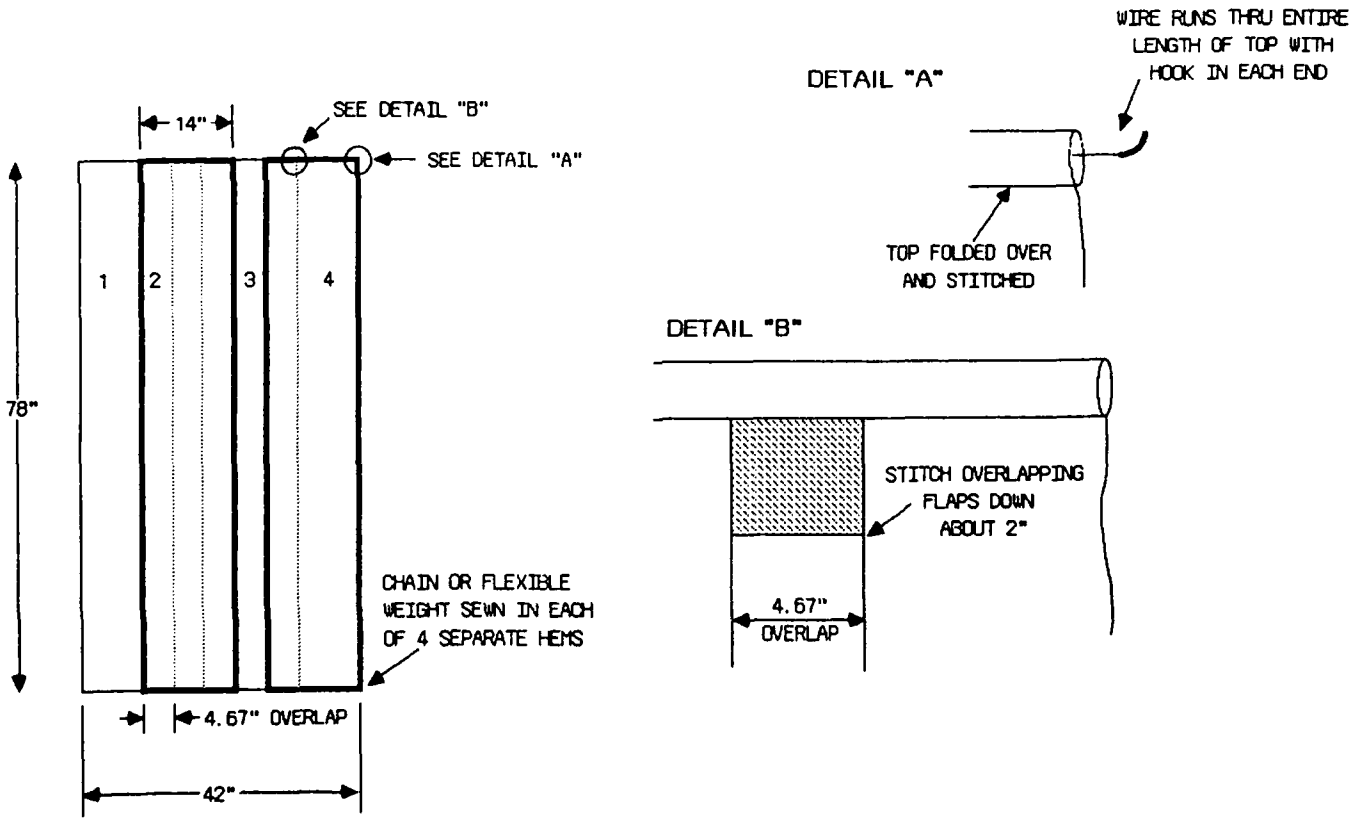


Fig. 2. Multiple-strip curtain design.

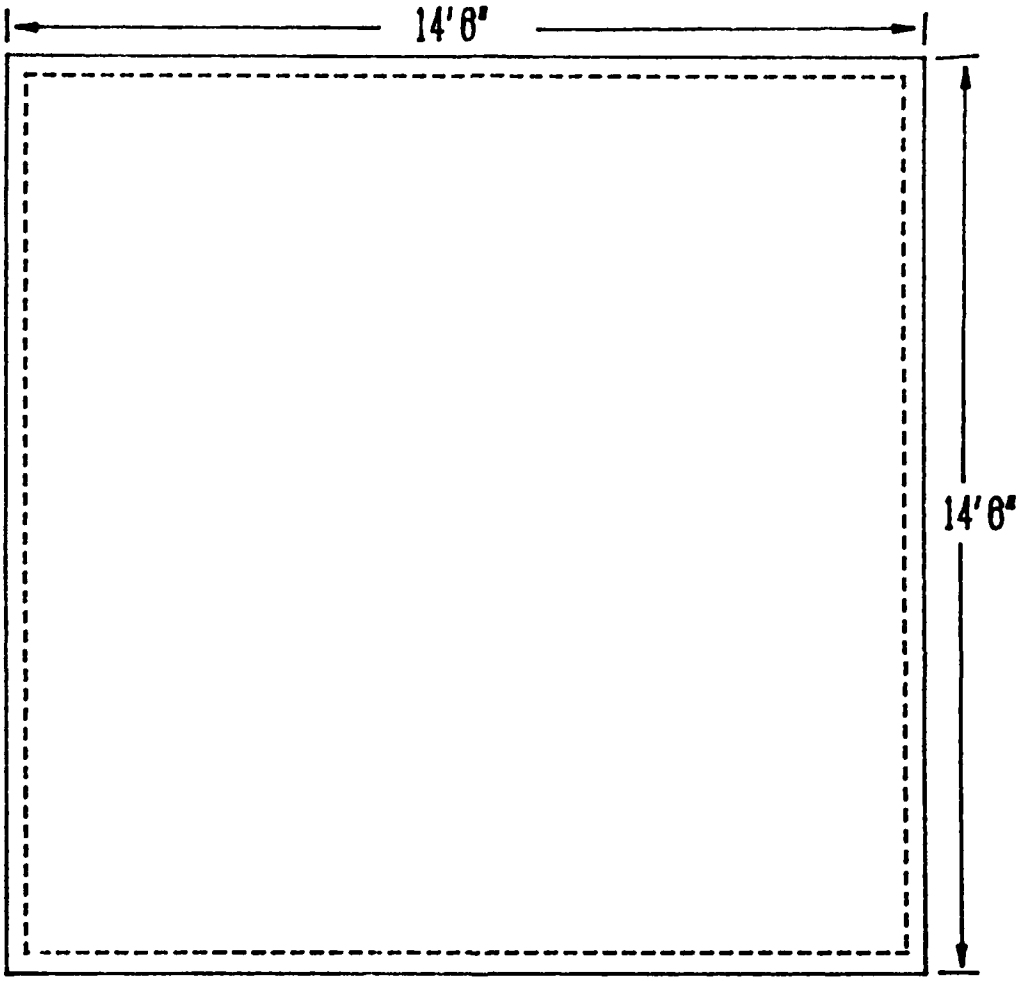


Fig. 3. Prototype blanket design.

We fabricated the tunnel or "elephant trunk" design shown in Figure 4. The trunk was fastened around the lip of an archway, door, or hatch. The remaining material was designed to fall flush with the deck to create a "tunnel" that separated the dirty and clean sides, Figure 5.

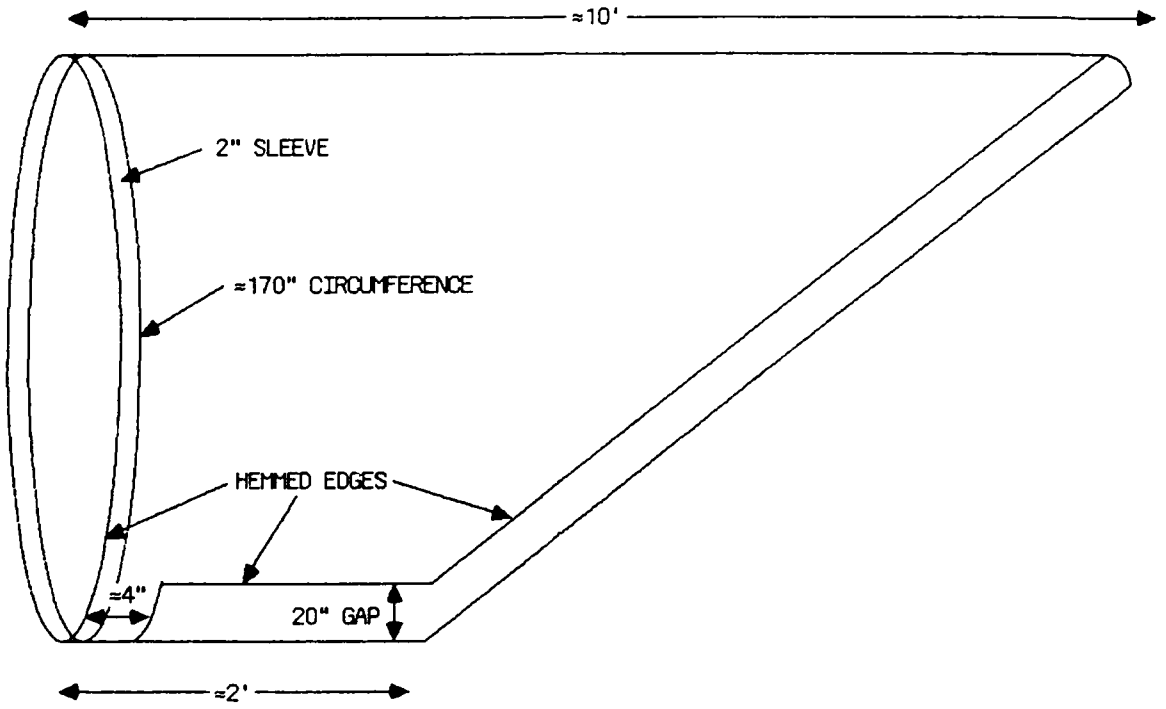


Fig. 4. Prototype elephant trunk design.

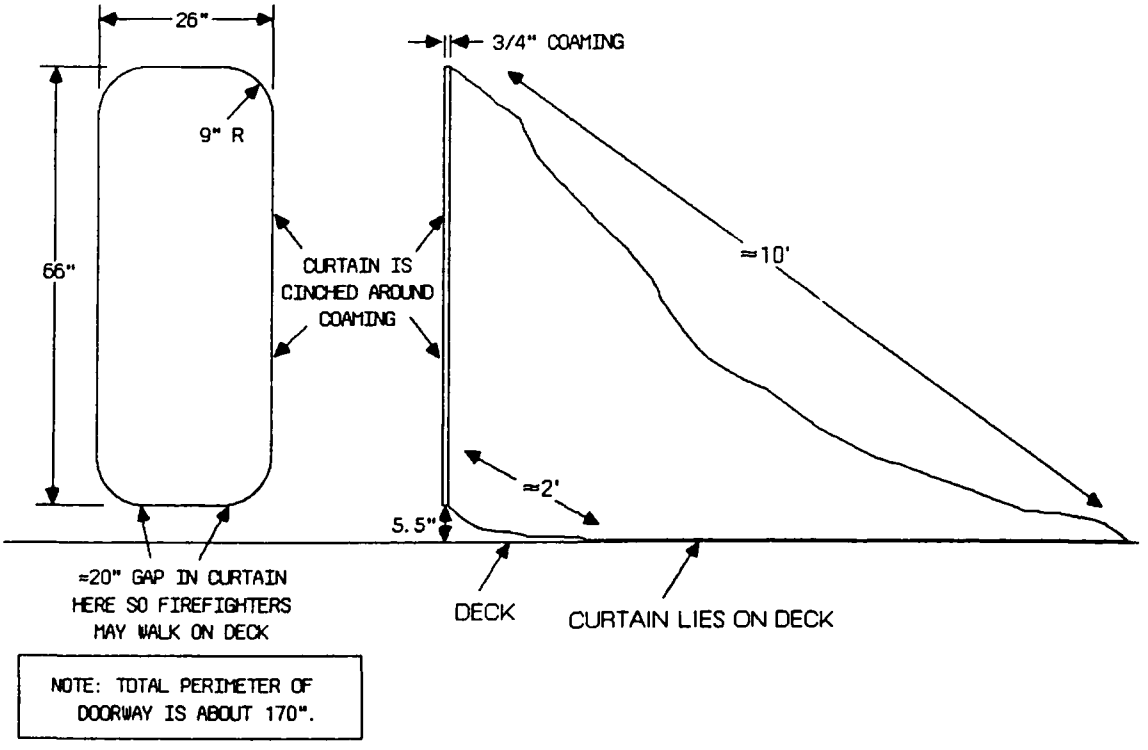


Fig. 5. Elephant trunk installed on archway.

MATERIALS

The four materials used to manufacture the portable smoke curtains are listed in Table 1. While the portable smoke curtain was not intended to be a fire boundary, we chose materials with good fire-resistant properties. Three of the four materials weighed 10 oz/yd^2 (0.34 kg/m^2). The Siltemp material weighed 22 to 41 oz/yd^2 (0.76 to 1.37 kg/m^2). Siltemp is a silica type of fabric with a silicone coating, which improves its resistance to abrasion and its surface impermeability to liquids.

Table 1. Materials chosen for the prototype portable smoke curtains.

Material	Manufacturer
PBI-Kevlar[TM]	Southern Mills
Nomex	Southern Mills
Siltemp	Ametek
Kynol	Chemical Fabric Corporation

ATTACHMENT DEVICES

We considered several methods to deploy the curtain. One was a metal wire sewn through the entire length of the top of the curtain with a snap hook on each end. Eyes were mounted on each side of the openings where we wanted to install the curtains. As an alternative to permanently mounting the eyes, we investigated the use of eyes mounted with suction cups and magnets. In addition, we tried spring-loaded clips, C-clamps, and vice grip pliers. The pliers or clips were fastened to the combing of the opening at strategically selected locations. We also considered the use of a spring-loaded shower curtain rod.

[TM]Kevlar is a trade name of E.I. du Pont de Nemours and Company.

TEST AND EVALUATION

TESTS ON EX-USS BARRY

Portable smoke curtain prototype attaching methods were tested at the Navy Yard in Washington, DC, on EX-USS BARRY. The use of snap hooks was eliminated because it would be difficult to align them with the eyes in a smoke-filled environment. Magnets and suction cups were eliminated because they did not hold their position under the shear stress created by the weight of the curtain. When used correctly, spring clamps proved to be a reliable method for installing the portable smoke curtains in archways and doors. C-clamps, vice grips, and the spring-loaded shower curtain rod were tested at the USCG Fire and Safety Detachment, Mobile, AL.

LIVE FIRE TESTS ON ALBERT E. WATTS

All four portable smoke curtain prototypes were evaluated at the USCG Fire Safety and Test Facility onboard ALBERT E. WATTS in October 1986. The evaluation was a combined effort among this Center, the Naval Research Laboratory, personnel from USS SPRUANCE, and the U.S. Coast Guard. These tests demonstrated that portable smoke curtains can be deployed successfully and reduce the spread of smoke during a fire. We found lightweight and abrasion-resistant materials, such as PBI Kevlar, Kynol, Nomex or their equivalent, are easier to install and more durable than Siltemp. The silica cloth started to tear after a couple of installations, which allowed smoke to penetrate the curtain. Further, the cloth was about three times heavier than the other three materials which made installation difficult and slow.

USS SPRUANCE (DDG 963) provided the manpower necessary to fight the fire. Once trained by Center representatives, the fire-fighting team was able to deploy portable smoke curtains during a fire when the passage was completely obscured. The curtains created a barrier to contain smoke on the fire side and to allow smoke removal on the "non-fire" side of the curtain. Successful installations such as the blanket design,

Figure 6, and the two-strip design, Figure 7, demonstrate the feasibility of integrating portable smoke curtains into fire fighting.

Fig. 6. Blanket design installed on Ladder 02 deck.

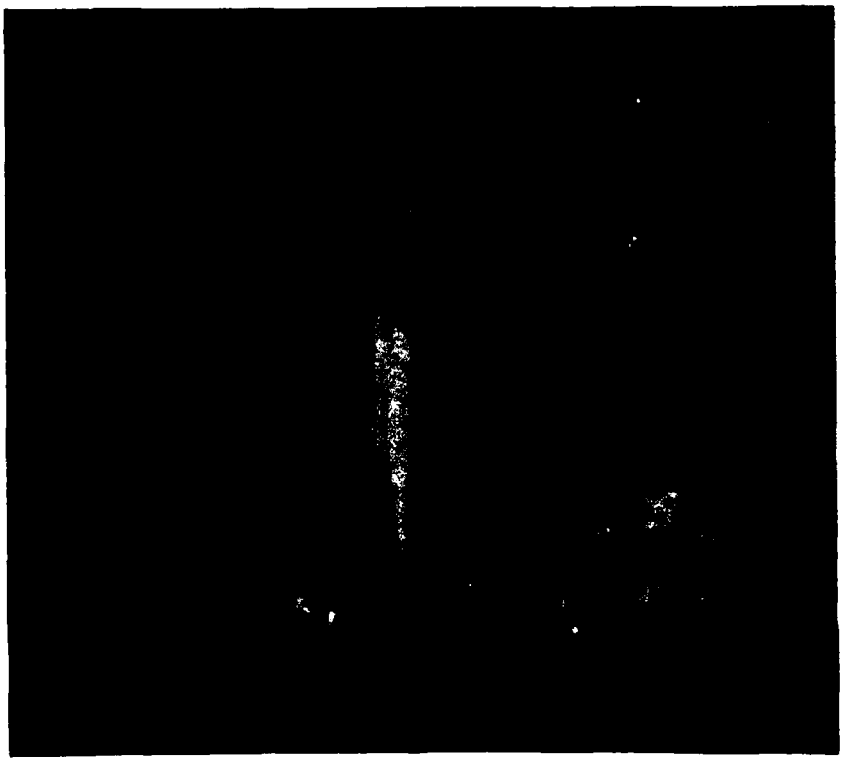


Fig. 7. Two-strip design installed in archway.

While the multiple-strip design was easy to deploy, it allowed smoke to penetrate at a faster rate than the two-strip design. Installation of the elephant trunk design was cumbersome, time-consuming, and allowed smoke to spread through the bottom gap.

The use of C-clamps and vice grips as attaching devices was difficult because both required firefighters in full protective clothing to make adjustments to fit each combing or door frame. Spring clamps required no adjustment, and the clamping force at the jaw of the spring clamp was strong enough to hold the curtain in place during the fire-fighting effort. The key factor was to place the clamps strategically at points around the doorway to reduce penetration of smoke and hot gases at the top of the curtain; see Figure 8.

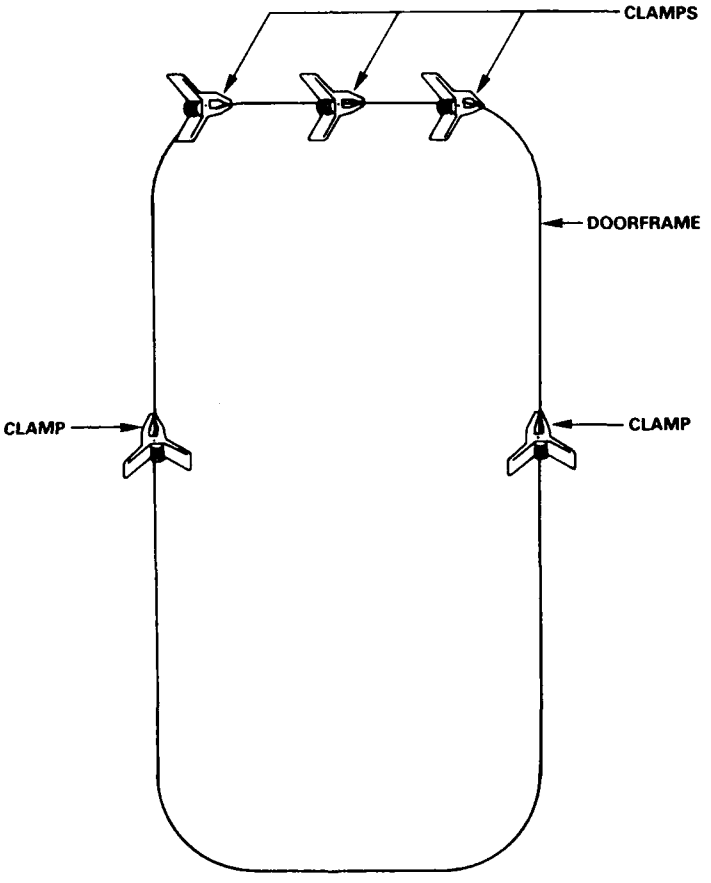


Fig. 8. Clamp installation pattern.

The spring-loaded shower rod was deleted from consideration because it was not usable universally. The use of snaps with an eyelet installed, magnetically mounted eyes, and eyelets mounted with a suction cup were eliminated also.

DESIGN IMPROVEMENTS

During tests on EX-USS BARRY, we determined that the use of snap hooks was not practicable. This eliminated the wire which ran through the entire length at the top of the curtain using snap hooks. Other design modifications were made as a result of tests conducted on WATTS.

1. The hook and pile strip that joined the two strips in the two-strip design was reduced to 2 ft (0.6 m) from the top down. Initial design from top to bottom made penetration of the curtain slightly difficult. A tight seal is needed only at the top of the curtain where most of the hot gases and smoke occur. The overlap of the two strips compensated for the elimination of the hook and pile at the bottom.
2. A luminiscent strip was added at the edge where the two strips overlap and at the top center of the curtain on both sides. This allows a firefighter to find the inner edge of the strip quickly and penetrate the smoke curtain. The strip provided at the top permits quick access to the top center of the curtain to be matched with the top center of the doorway.
3. The concept of a viewing port was discarded because the port becomes useless once it is covered with smoke.

SMOKE CURTAIN DESIGN SPECIFICATIONS

We prepared preliminary engineering drawings of the two-strip and blanket designs which were used to prepare the NAVSEA standard drawings shown in Appendix A.

CURTAIN FOLDING PROCEDURES AND INSTALLATION

Our first attempt to deploy the curtains showed that preparation of the curtain prior to use was critical for rapid and proper installation. Two factors were considered in developing the folding procedures: storage and the ease with which the curtain could be unfolded.

TWO-STRIP CURTAIN

The smoke curtain must be folded so that it may be unfolded in less than 10 seconds and provide the user with easy access to the center top section. This eliminates the need to locate that crucial section under obscured conditions. Figure 9 illustrates the folding process and shows proper installation for the two-strip design. Curtains that are to be reused and stored also must be folded in this manner.

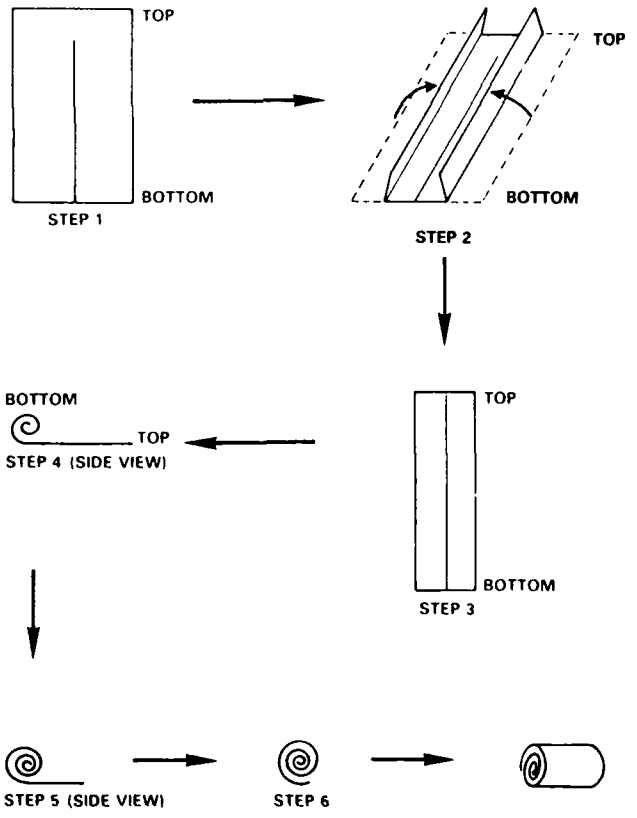


Fig. 9. Folding steps for the curtain in the two-strip design.

A 6-in. (15.2-cm) overlap must be allowed when folding the sides toward the center of the curtain (Step 2) to ensure that the final shape is cylindrical with an 18-in. width (45.6-cm) and a diameter of 7 to 8 in. (17.8 to 20.3 cm). The curtain is rolled from bottom to top. Spring clamps can be stored in the outer roll of the curtain but must be removed before the smoke curtain team enters the obscured area.

When deployed, the firefighter holds the curtain by the loose end (top) at the folds, and a second firefighter carries the spring clamps. The team approaches the fire in a low position; as they reach the door or archway, the firefighter allows the roll to fall on the deck, still holding the curtain at the folds. Then, he rises slowly, using the curtain as a shield between the fire and himself and places his hands at the beginning of the top curve of the arch. Next, the second firefighter rises and using the curtain as a shield, locates the hands of the first firefighter, and places a spring clamp next to his hands. The clamps are distributed as shown in Figures 6 and 8. Maximum deployment time for the curtain in total obscuration should not exceed 2 minutes after reaching the door or archway. Smoke removal then can begin on the non-fire side of the curtain.

SMOKE BLANKET

The smoke blanket is folded four times (Figure 10) and then rolled as it was in the two-strip design. A cylindrical shape is attained that is approximately 11 in. wide (28 cm) with a diameter of 18 in. (45.6 cm). The spring clamps may be stored in the outer roll of the curtain but must be removed before entering the obscured area.

The blanket curtain must be held by the loose end (as in the two-strip design), allowed to unroll on the deck, then unfolded four times before it is installed. The curtain is laid over the hatch or deck opening, making sure that the opening is covered completely; then spring clamps are applied as necessary to help hold the blanket in position.

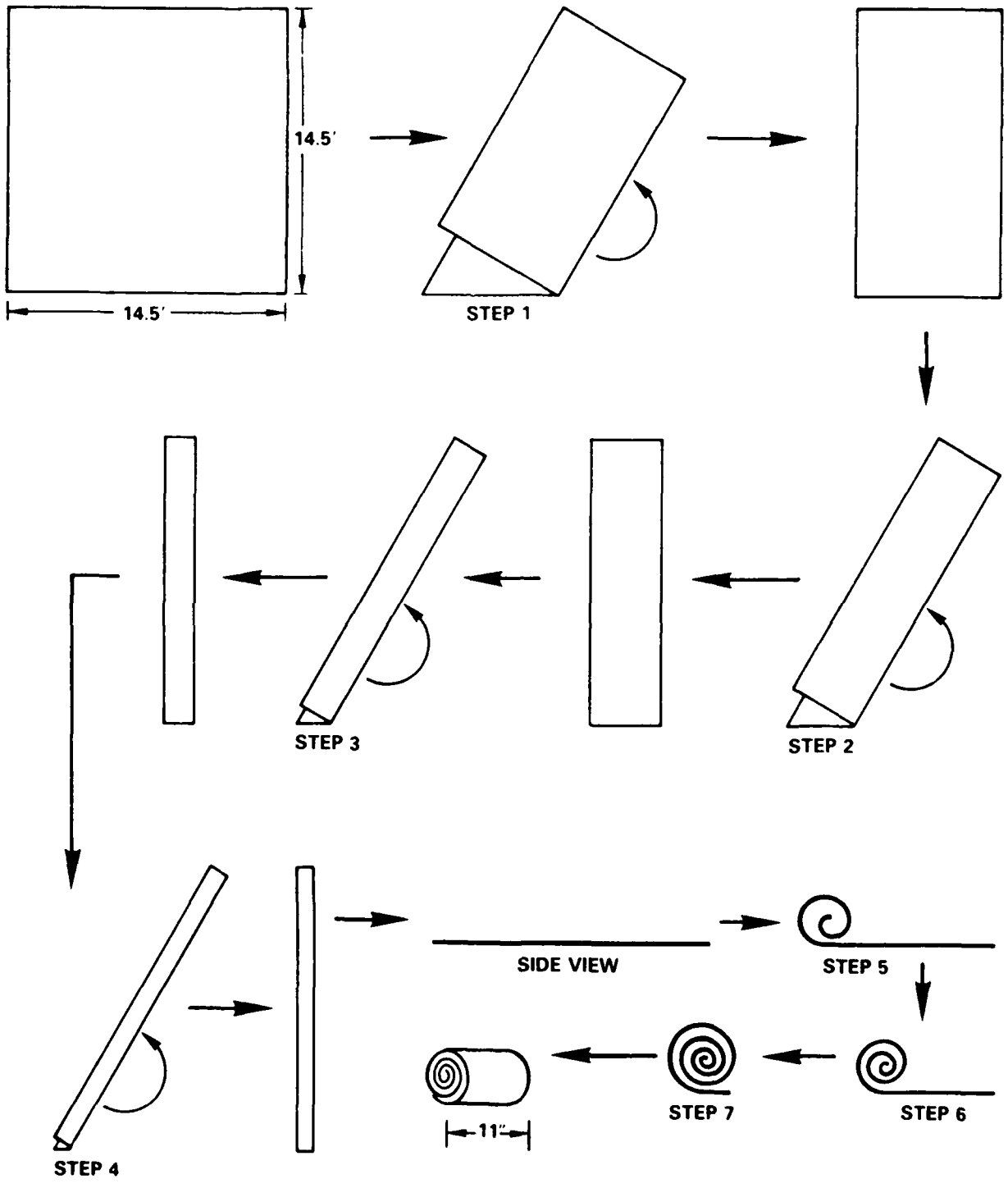


Fig. 10. Folding steps for the blanket design.

CONCLUSIONS

Our studies of the use of portable smoke curtains have resulted in the following conclusions.

1. The curtains will reduce the spread of smoke when properly installed.
2. The curtains can be installed successfully by a fire-fighting crew trained in the procedure.
3. The use of spring clamps proved to be quick, simple, and effective.
4. Folding and unfolding procedures are critical, and could determine the success of the installation.

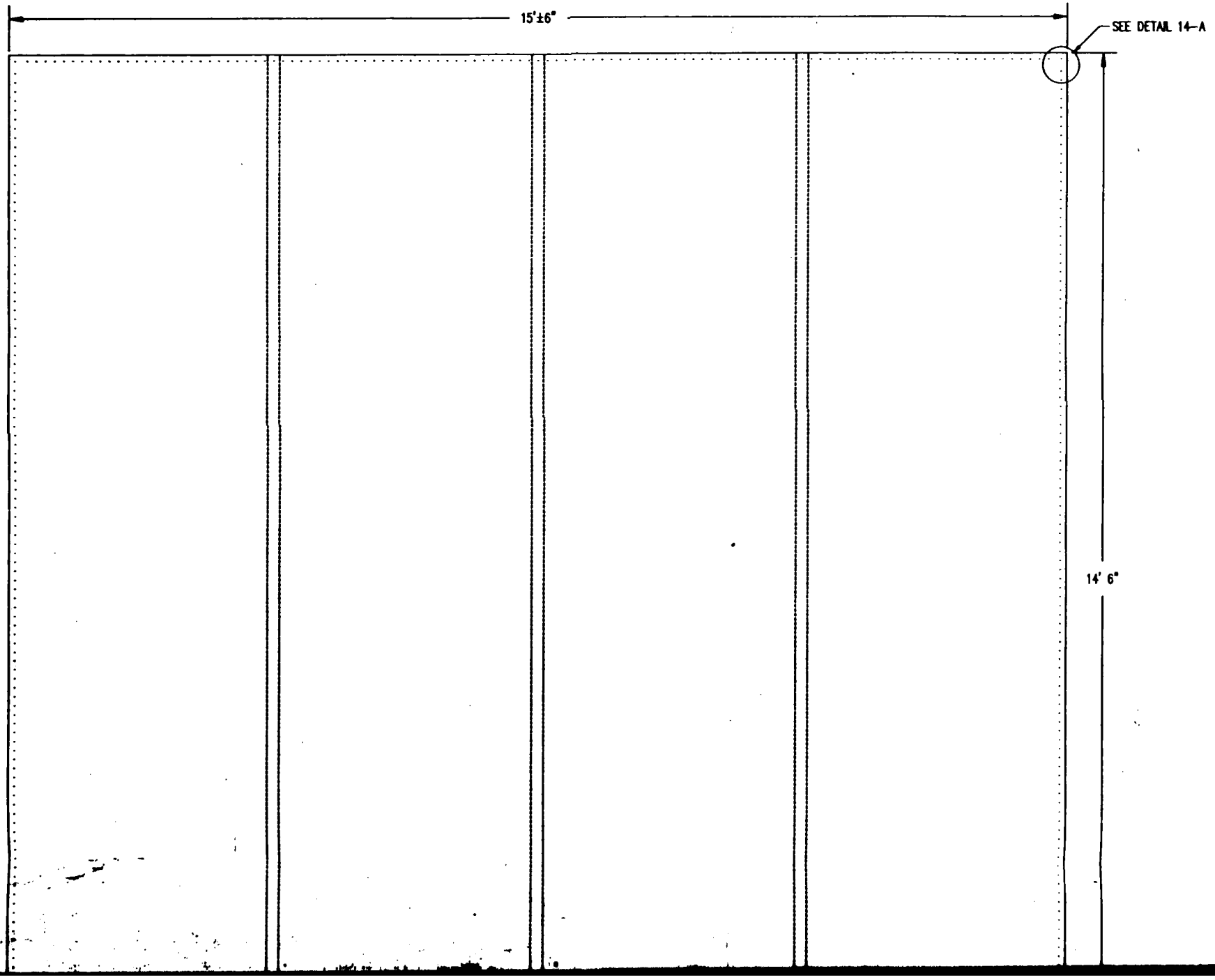
RECOMMENDATIONS

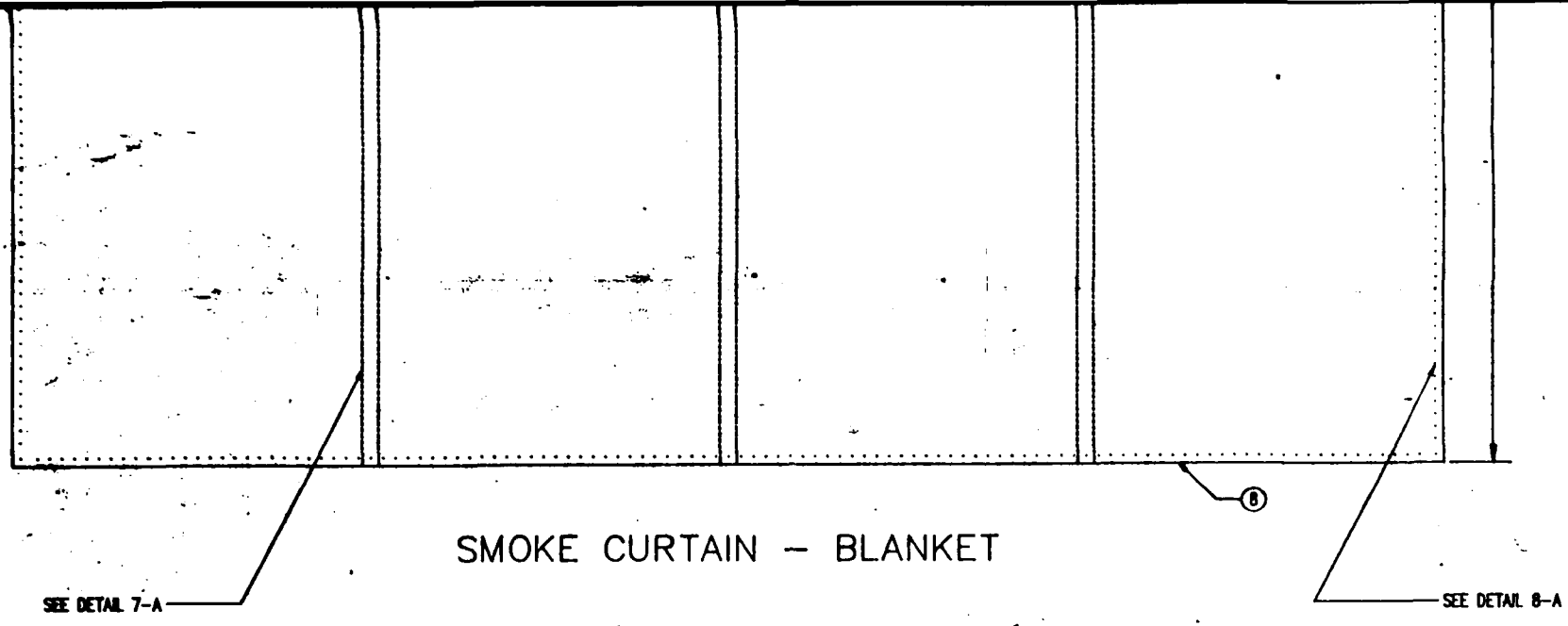
Based on observations and results of tests conducted in this study, we recommend the following.

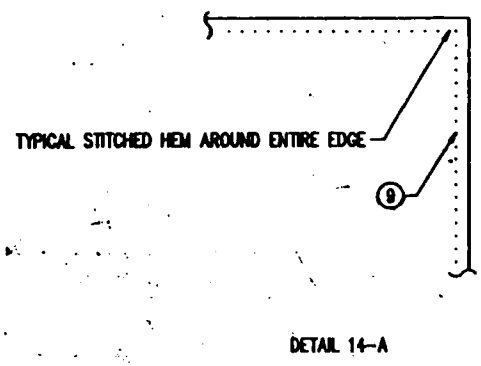
1. Smoke curtains be integrated into the fire-fighting doctrine.
2. The Navy pursue the effort to have portable smoke curtains delivered to the Fleet.

APPENDIX A

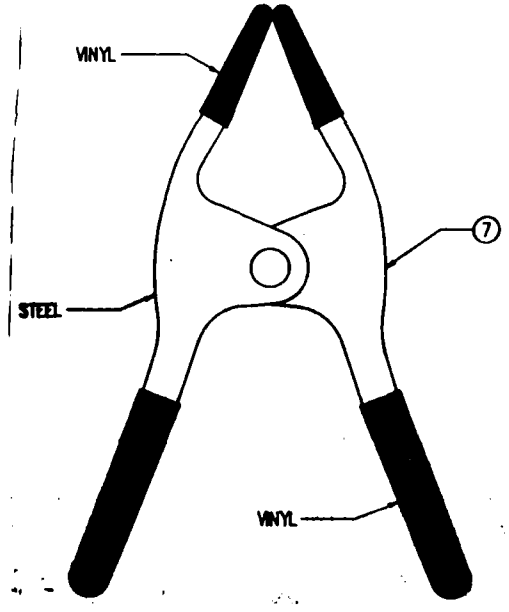
NAVSEA STANDARD DRAWINGS OF THE TWO-STRIP AND BLANKET DESIGNS


15'±6"
SEE DETAIL 14-A
14' 6"





DETAIL 14-A



SPRING CLAMP

Smoke Curtain, Blanket Design

GENERAL NOTES

1. UNLESS OTHERWISE NOTED, ALL HIDDEN LINES ARE SYMBOLIZED BY (---), ALL STITCHES ARE SYMBOLIZED BY (- - - -), AND ALL SEAMS ARE SYMBOLIZED BY (===).

2. EACH PANEL SHALL BE HEMMED ON THREE SIDES AND THE FOURTH SIDE (BOTTOM) SHALL HAVE A SLEEVE (3"). TWO PANEL CURTAINS ONLY.

3. CHAIN LENGTH OF 25 INCHES SHALL BE SEWN INTO SLEEVE AT BOTH ENDS OF EACH PANEL. TWO PANEL CURTAIN ONLY.

4. FOUR FIRE RETARDANT REFLECTIVE STRIPS (PC. NO. 5 AND PC. NO. 6) ARE REQUIRED PER TWO PANEL CURTAIN (2 REFLECTIVE STRIPS REQUIRED PER SINGLE PANEL). ONE REFLECTIVE STRIP 2" x 48" LOCATED AT OVERLAP EDGE OF EACH PANEL. ONE REFLECTIVE STRIP 2" x 8" LOCATED AT CENTER OF TWO PANEL CURTAIN (FRONT AND BACK).

5. THE TWO PANEL CURTAIN IS TO BE USED FOR VERTICAL DOORS OR ARCHWAYS AND THE BLANKET DESIGN FOR SCUTTLES OR HATCHES.

6. INSERT LABEL IN STITCHING OF BOTTOM HEM IN THE CORNER OF THE CURTAIN OR BLANKET. STITCHING SHALL NOT BE THROUGH ANY PRINTING. LABEL SHALL BE AS SPECIFIED BY NAVAL SEA SYSTEMS COMMAND, DAMAGE CONTROL BRANCH, WASHINGTON, D.C. 20362.

7. A PANEL ON THE TWO PANEL CURTAIN MAY BE CONSTRUCTED BY USING A MAXIMUM OF TWO CLOTH PIECES OF NOT LESS THAN 6 INCHES IN WIDTH SO THAT THE FINISHED PANEL MEASURES 25 INCHES EXCLUDING HEMS, BUT INCLUDING SEAMS.

8. FOUR PANELS SHALL BE USED TO CONSTRUCT THE BLANKET. EACH OF THE FOUR PANELS SHALL BE EQUAL IN LENGTH AND WIDTH AND WHEN STITCHED TOGETHER SHALL EQUAL THE FINISHED MEASUREMENTS.

9. THE REFLECTIVE STRIPS SHALL BE 2 INCHES WIDE OF FIRE RETARDANT MATERIAL (3M-8486) OR EQUIVALENT.

10. CURTAIN MATERIAL SHALL BE AS SPECIFIED BY NAVAL SEA SYSTEMS COMMAND, DAMAGE CONTROL BRANCH, WASHINGTON, D.C. 20362.

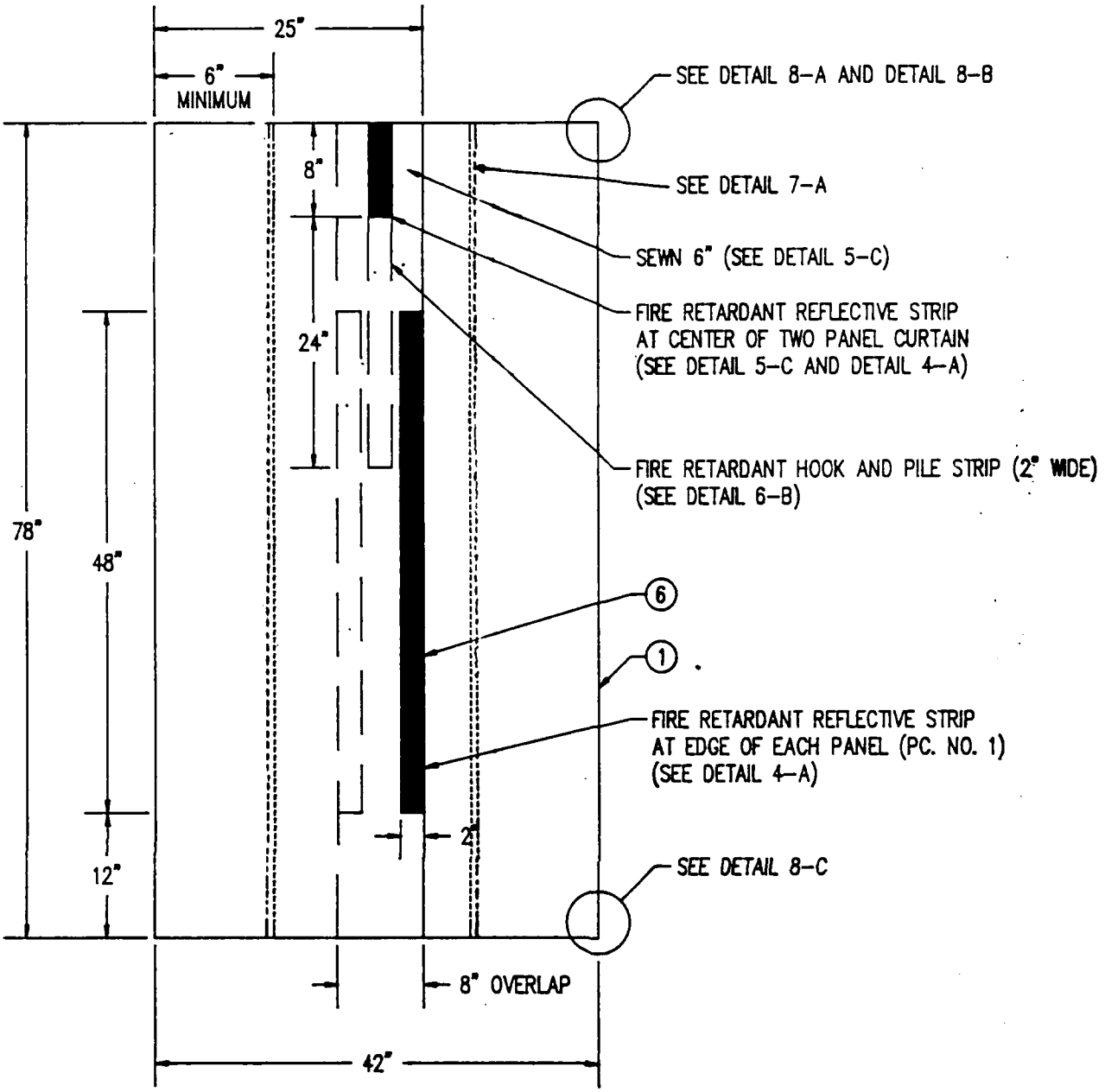
11. ALL SEAMS, HEMS, AND STITCHING SHALL CONFORM TO FED-STD-751.

NO REQ	PC NO	DESCRIPTION	MATERIAL	MATL SPEC	REMARKS	REF DWG
50 YDS	8	THREAD FOR CURTAIN, BLANKET	FIBERGLASS	ASTM D4030		
25 SQ YD	6	CURTAIN,BLANKET	FIBERGLASS	SEE NOTE 10		
5	7	SPRING CLAMP, 6 IN.	STEEL	COMMERCIAL		
2	6	REFLECTIVE STRIP, 2"W x 48"L	FIRE RETARDANT	COMMERCIAL	SEE NOTE 9	
2	5	REFLECTIVE STRIP, 2"W x 8"L	FIRE RETARDANT	COMMERCIAL	SEE NOTE 9	
1	4	FASTENER,2"W x 24"L,(HOOK AND PILE MATING)	HOOK & PILE FAST. TYPE I,CLASS 1	MIL-F-21840		
100 YDS	3	THREAD FOR CURTAIN, TWO PANEL	FIBERGLASS	ASTM D4030		
2	2	CHAIN, 1/4" LINK, 25"LONG,1 LB/FT	BRASS OR ZINC PLATED STEEL	COMMERCIAL	SEE NOTE 3	
2	1	CURTAIN,TWO PANEL, 27"W x 82"L	FIBERGLASS	SEE NOTE 10		

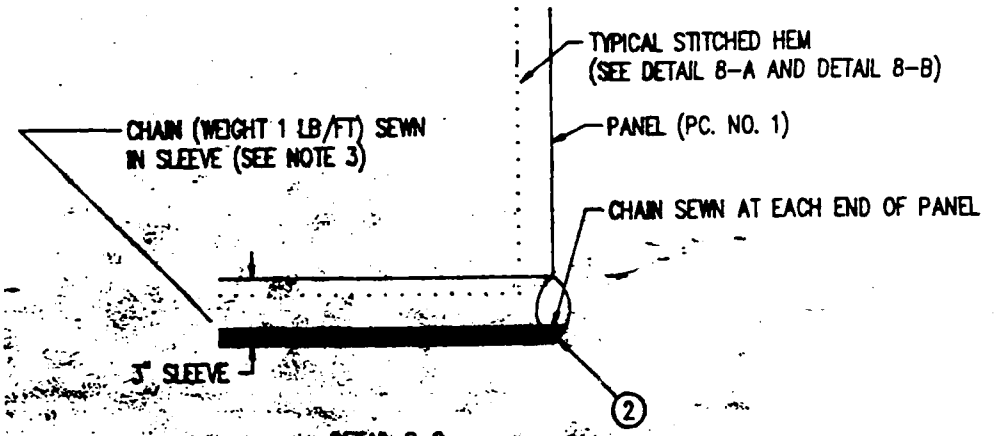
PARTS LIST

Smoke Curtain, Two Panel Design

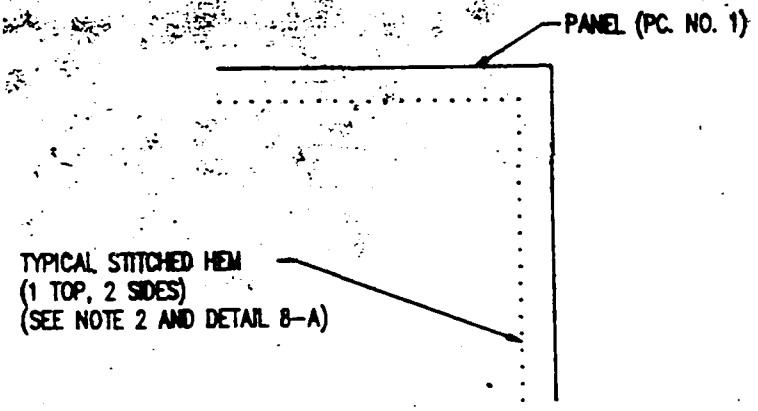
182



SMOKE CURTAIN - TWO PANEL



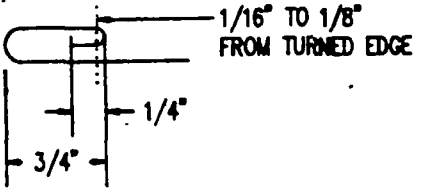
DETAIL 8-C
NO SCALE



DETAIL 8-B
NO SCALE

HEM

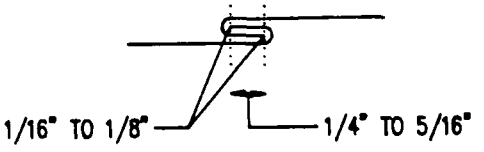
301 STITCH TYPE



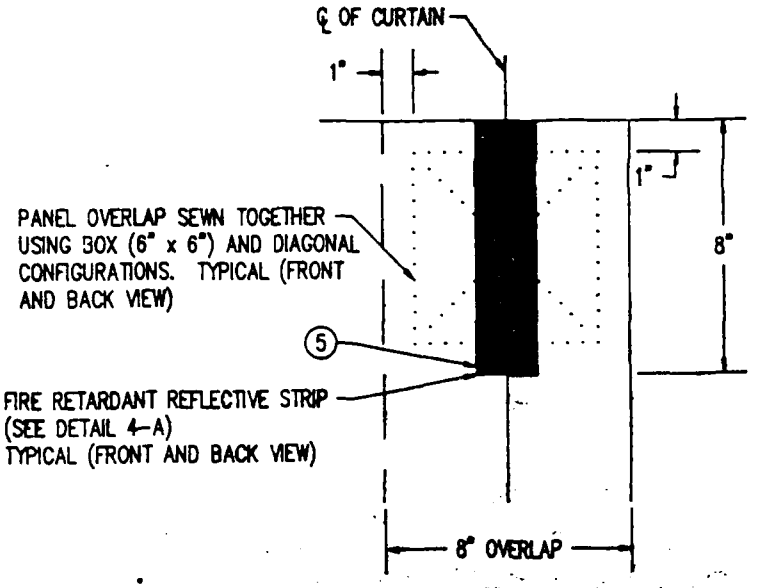
DETAIL 8-A

SEAMS

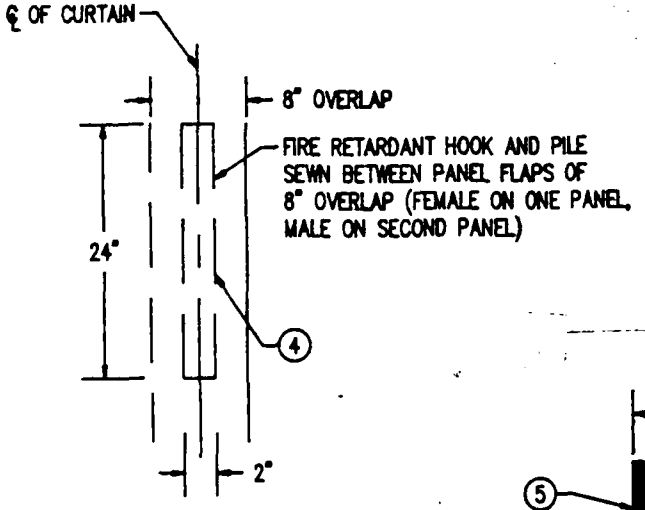
LSc-2 (301 STITCH TYPE)



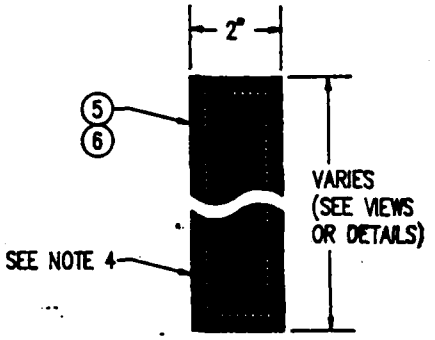
DETAIL 7-A



DETAIL 5-C
NO SCALE



DETAIL 6-B
NO SCALE



STITCHED 1/4" IN FROM EDGES (TYPICAL)

DETAIL 4-A
NO SCALE

202

INITIAL DISTRIBUTION

Copies	
8	NAVSEA 2 SEA 05R23 (C. Pohler) 2 SEA 55X22 (C. Loiser, M. Campbell) 2 SEA 56Y52 (D. Kay, B. Froh) 2 Library
1	CNA
12	DTIC

CENTER DISTRIBUTION

Copies	Code	Name
1	1202	S. Cohen
1	28	G. Wacker
1	2801	J. Crisci
1	2801	D. Ventriglio
1	2802	T. Morton
1	2803	J. Cavallaro
1	2809	A. Malec
1	281	J. Gudas
3	283	H. Singerman
3	2833	M. Greenberg
3	2833	R. Carey
3	2833	L. Vazquez
1	284	E. Fischer
1	522.1	Unclass Lib (A)
2	5231	Office Services